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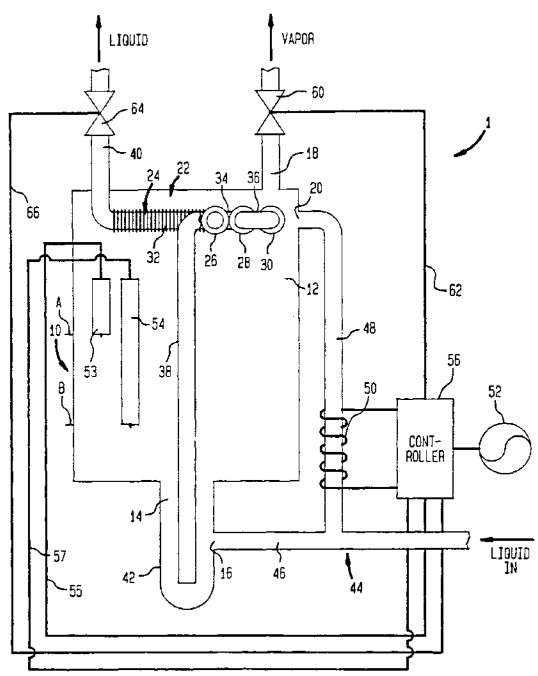
(54) **Cryogen delivery apparatus**

(57) A cryogen delivery apparatus 1 for delivering cryogen in a saturated state includes a vessel 10 which contains the cryogen in liquid and vapour phases. The vessel 10 has a headspace region 12 and a heat exchanger 22 located within the headspace region 12 for indirectly exchanging heat between the vapour located within the headspace region and a liquid stream composed of the liquid phase of the cryogen. If the cryogen is introduced into the vessel 10 as a subcooled liquid through an inlet 46, the subcooled liquid flows through a withdrawal tube 38 to the heat exchanger 22 and is warmed by passage therethrough and thereby converted into a saturated liquid. The saturated liquid is discharged from a liquid outlet 40 connected to the heat exchanger 22. In the event the liquid enters the vessel as two-phase flow, the vessel 10 acts as a phase separator. A branched supply line 44 is provided having a liquid inlet branch 46 connected to the bottom liquid inlet 46 of the vessel 10 so that a supply stream composed of the cryogen flows into the vessel 10. A vapour inlet branch 48 of the supply line 44 is connected to an inlet 20 to the headspace 12. A heating element 50 is provided to heat the vapour inlet branch 48 so that liquid cryogen is vaporised to replenish vapour within the headspace that is depleted through condensation on the external surfaces of the heat exchanger 22 or discharge from a vapour discharge outlet 18 of the vessel 10.

FIG.



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Description

The present invention relates to a cryogen delivery apparatus for delivering a cryogen in a saturated state. More particularly, the present invention relates to such an apparatus in which a vessel serves as a phase separator if the cryogen to be delivered is supplied as a two phase flow. The vessel contains a heat exchanger to convert subcooled liquid into a saturated liquid if the cryogen is supplied as a subcooled liquid.

Cryogenic fluids such as liquid air or liquefied components of air are utilised in many cryogenic cooling and refrigeration applications. A common problem with supplying a cryogenic fluid is that the degree of cooling potential of the cryogenic fluid can vary with the condition of the fluid being supplied. For instance, subcooled liquid nitrogen has a different cooling potential from nitrogen supplied as a two phase flow. This problem is exacerbated in cooling applications that do not employ a feedback control system, but rather, rely on timers and the like to open and close cryogenic supply valves. An example of such a problematic application is where a cryogen is used in cooling blow moulded plastic articles after having been formed. In many systems designed for such an application, the flow of the cryogen for each cooling cycle is controlled by a control valve which is opened for a pre-determined time period. The two phase flow form of the cryogen will have less cooling potential than the cryogen as a subcooled liquid. Moreover, the amount of subcooled liquid that is supplied for a given valve opening will be greater than that of the cryogen supplied as a two phase flow due to the increased density of the subcooled liquid. Since the cooling potential of the cryogen will vary with its physical state, either plastic parts will not be cooled sufficiently or the cryogen will be wasted.

As will be discussed the present invention provides a practical solution to alleviate the problem set forth above by providing a cryogen delivery apparatus that serves as an interface between the liquid cryogen being supplied and the particular application for which the cryogen is being used. The interface provided by the present invention is one that insures that the cryogen will be consistently utilised in a saturated state.

According to the present invention there is provided cryogen delivery apparatus for delivering a cryogen in a saturated state, said cryogen delivery apparatus comprising:

a vessel for containing said cryogen in liquid and vapour phases and for phase separating said cryogen into said liquid and vapour phases in the event that said cryogen is introduced into said vessel as a two phase flow;

said vessel having, a headspace region, an inlet for introducing said cryogen into a bottom region of said vessel, a vapour outlet for discharging vapour from said headspace region, and a headspace inlet for introducing vapour into said headspace region;

heat exchange means for indirectly exchanging heat between said vapour located within said headspace and a liquid stream composed of said liquid phase of said cryogen so that in the event that said cryogen is introduced into said vessel as a subcooled liquid, said vapour will condense into said liquid phase and said subcooled liquid will be converted into a saturated liquid;

a liquid outlet connected to said heat exchanger for discharging said liquid stream in saturated state from said vessel;

a branched supply pipeline having a liquid inlet branch connected to said bottom liquid inlet so that a supply stream composed of said cryogen flows into said vessel and a vapour inlet branch connected to said headspace inlet; and

heater means for heating said vapour inlet branch of said branched supply pipeline so that liquid cryogen is vaporised within said vapour inlet branch to produce said vapour in the event that said vapour within said headspace is depleted through condensation or through discharge through said vapour outlet.

In practice, the cryogen delivery apparatus in accordance with the present invention can have its branched supply line connected to a source of liquid nitrogen. In case such liquid nitrogen is in a two phase state, then, the cryogen delivery apparatus would serve simply to separate the phases into liquid and vapour phases, with the excess vapour being vented from the vessel. If however, the nitrogen storage tank were filled and the subcooling within the tank dramatically increased, then the heat exchange means would serve to exchange heat between the headspace vapour and the subcooled liquid being withdrawn to convert the subcooled liquid into saturated liquid upon its discharge from the vessel.

In the event that subcooled liquid is being supplied and/or vapour is being utilised, the liquid level within the vessel will tend to rise. In order to replace the vapour that has been depleted, vapour is supplied to the headspace region of the vessel through the heated vapour inlet branch of the supply line. It is to be noted that by simply heating only a stream of the liquid (as opposed to all of the liquid contained within the vessel), power requirements of a heater for such purpose can be minimised. The heating can be at a constant level, where requirements do not vary, or can be proportional to the use of liquid. The heater can be used at the conclusion of a batch process and in such case, evolved vapour will cause liquid to back-flow through the branched supply line.

It is to be noted that the term "cryogen" as used herein and in the claims means a liquefied atmospheric gas such as nitrogen, liquid air, other cold liquid substance which under standard ambient conditions would exist in a vapour state.

Apparatus according to the invention will now be described by way of example with reference to the accompanying drawing which is a schematic of a cryogenic delivery apparatus in accordance with the present invention.

With reference to the drawing, a cryogen delivery apparatus includes a vessel 10 adapted to contain cryogen in liquid and vapour phases. The vapour phase is contained within a head space region 12 of vessel 10. Cryogen enters a bottom region 14 of vessel 10 by means of a bottom inlet 16. A vapour outlet 18 is provided for discharging vapour from headspace region 12 of vessel 10. A headspace inlet 20 is also provided for introducing vapour into head space region 12 of vessel 10.

If the cryogen is supplied to vessel 10 in a state of two phase flow, then vessel 10 will act as a phase separator to separate the cryogen into the liquid and vapour phases. In this case, depending on whether the vapour is being supplied to an external process, the excess vapour will be periodically vented from the apparatus through vapour outlet 18. In the event that the liquid is subcooled, a means is provided for indirectly exchanging between the vapour located within the head space and a liquid stream composed of the liquid phase, which means is preferably a heat exchanger 22 located within head space region 12. Heat exchanger 22 is formed from finned tubing 24 which is arranged in series passes 26, 28, 30 and 32 which are connected by U-shaped fixtures 34 and 36. Liquid is introduced into heat exchanger 22 by means of a withdrawal tube 38 which is connected to pass 26 by means of a 90° elbow-like fixture which is shown broken away for purposes of ease of illustration. As can be appreciated, heat exchanger 22 could be constructed in any number of ways, including a simple coil of bare tubing. Heat exchanger 22 condenses vapour within head space region 12 and thus converts subcooled liquid into saturated liquid. The saturated liquid is discharged from vessel 10 through liquid outlet 40.

Vessel 10 is provided with a depending volume or sump 42 through which withdrawal tube 38 extends and has bottom inlet 16 defined therein. The withdrawal tube 38 extends below bottom inlet 16 in order to prevent vapour being drawn into heat exchanger 22 if the entering liquid is a two phase flow. The sump 42 is a preferred though optional feature of cryogen delivery apparatus 1.

Liquid level will tend to rise within cryogen delivery apparatus 1 as more subcooled liquid is converted into saturated liquid or as more vapour is discharged from vapour outlet 18. (It is to be noted that certain processes additionally require a supply of vapour from the apparatus 1 which must be replenished.) In order to increase the amount of vapour within head space region 12, a branched supply line 44 is provided having a liquid inlet branch 46 connected to bottom liquid inlet 16 so that liquid supply flows into vessel 10 and the vapour inlet branch 48 connected to head space inlet 20. A heater illustrated as a heating coil 50, connectable in electrical circuit with an electrical power source 52, heats incoming liquid and converts it to vapour. It is also to be noted that an electrical heater is only one of many possible means for heating vapour inlet branch 48. For instance, process heat from other heating sources could be used for the same purpose. The liquid level in branch 48 will be at the same level as inside the vessel, therefore no active control means is required to supply liquid to heater 50.

Although, as indicated above, electric current may be continually supplied to heating coil 50, in the illustrated embodiment, the operation of heating coil 50 is automatically controlled in response to the level of liquid within vessel 10. To this end, a level detector 53 is provided to sense an upper level of liquid within vessel 10. Such upper level is designated by reference "A". A lower level of liquid, designated by reference "B" is sensed by level detector 54. Level detectors 53 and 54 are "point level detectors" (of the type illustrated in US Patent 5,167,154) which are designed to generate signals when liquid level has risen to level A or has fallen below level B. It is understood that Thermocouples of electromechanical devices, or other means, may be used to sense the level of liquid. Additionally, although not illustrated, level detectors 53 and 54 could be set in wells to prevent their sensing of liquid height from being influenced by disturbances to the liquid within vessel 10. Alternatively, a continuous level detector, such as a capacitance type probe, could replace both level detectors 53 and 54.

An electrical connection 55 is provided to connect level detector 53 to a controller 56. Similarly an electrical connection 57 is provided to connect level detector 54 to controller 56. Controller 56 is either an analog or programmable logic controller. When the liquid level of the liquid phase rises to level A, controller 56, responsive to level detector 53, supplies electrical current, provided by power source 52, to heating coil 50. This control causes liquid to be vaporised and the vapour to flow into head space region 12. When the level falls below A again, the heating coil 50 is de-energised. In the event that the liquid level falls below level B, controller 56 acting in response to level detector 54 activates a remotely activated valve 60 connected to vapour discharge outlet 18 to open and discharge vapour. Remotely activated valve 60 is connected to controller 56 by an electrical connection 62. When the liquid level rises to B again the valve 60 closes. In such manner the liquid level will be constrained to remain within the range of height that is defined between levels A and B. Preferably, heating coil 50 or other heating source is positioned on vapour inlet branch 48 so that it is below liquid level A to prevent it from acting to superheat vapour evolved from the liquid. More preferably, heating coil 50 is positioned below liquid level B.

Controller 56 might also be used to trigger the supply of liquid in response to process requirements. To this end, a remotely operated valve 64 is illustrated as being in outlet 42. Remotely operated valve 64 is electrically connected via electrical connection 66 to controller 56. Depending on the process requirements additional outlets from the liquid or vapour space could be provided.

Claims

1. A cryogen delivery apparatus for delivering a cryogen in a saturated state, said cryogen delivery apparatus comprising:

a vessel for containing said cryogen in liquid and vapour phases and for phase separating said cryogen into said liquid and vapour phases in the event that said cryogen is introduced into said vessel as a two phase flow;

said vessel having, a headspace region, an inlet for introducing said cryogen into a bottom region of said vessel, a vapour outlet for discharging vapour from said headspace region, and a headspace inlet for introducing vapour into said headspace region;

heat exchange means for indirectly exchanging heat between said vapour located within said headspace and a liquid stream composed of said liquid phase of said cryogen so that in the event that said cryogen is introduced into said vessel as a subcooled liquid, said vapour will condense into said liquid phase and said subcooled liquid will be converted into a saturated liquid;

a liquid outlet connected to said heat exchanger for discharging said liquid stream in saturated state from said vessel;

a branched supply pipeline having a liquid inlet branch connected to said bottom liquid inlet so that a supply stream composed of said cryogen flows into said vessel and a vapour inlet branch connected to said headspace inlet; and

heater means for heating said vapour inlet branch of said branched supply pipeline so that liquid cryogen is vaporised within said vapour inlet branch to produce said vapour in the event that said vapour within said headspace is depleted through condensation or through discharge through said vapour outlet.

2. A cryogen delivery apparatus according to claim 1, wherein said heat exchange means comprises a heat exchanger located within said headspace and a withdrawal tube in communication with said heat exchanger and depending therefrom to draw said liquid cryogen from said vessel to said heat exchanger.

3. A cryogen delivery apparatus according to claim 1 or claim 2, wherein said heater means comprises an electrical heating coil to heat said vapour inlet branch.

4. A cryogen delivery apparatus according to any one of the preceding claims, adapted said cryogen delivery apparatus also comprises level detector means for detecting when said liquid phase rises above an upper set point level and means responsive to said level detector means for activating said heater means when said liquid phase rises above said upper set point level.

5. A cryogen delivery apparatus according to claim 4, wherein:

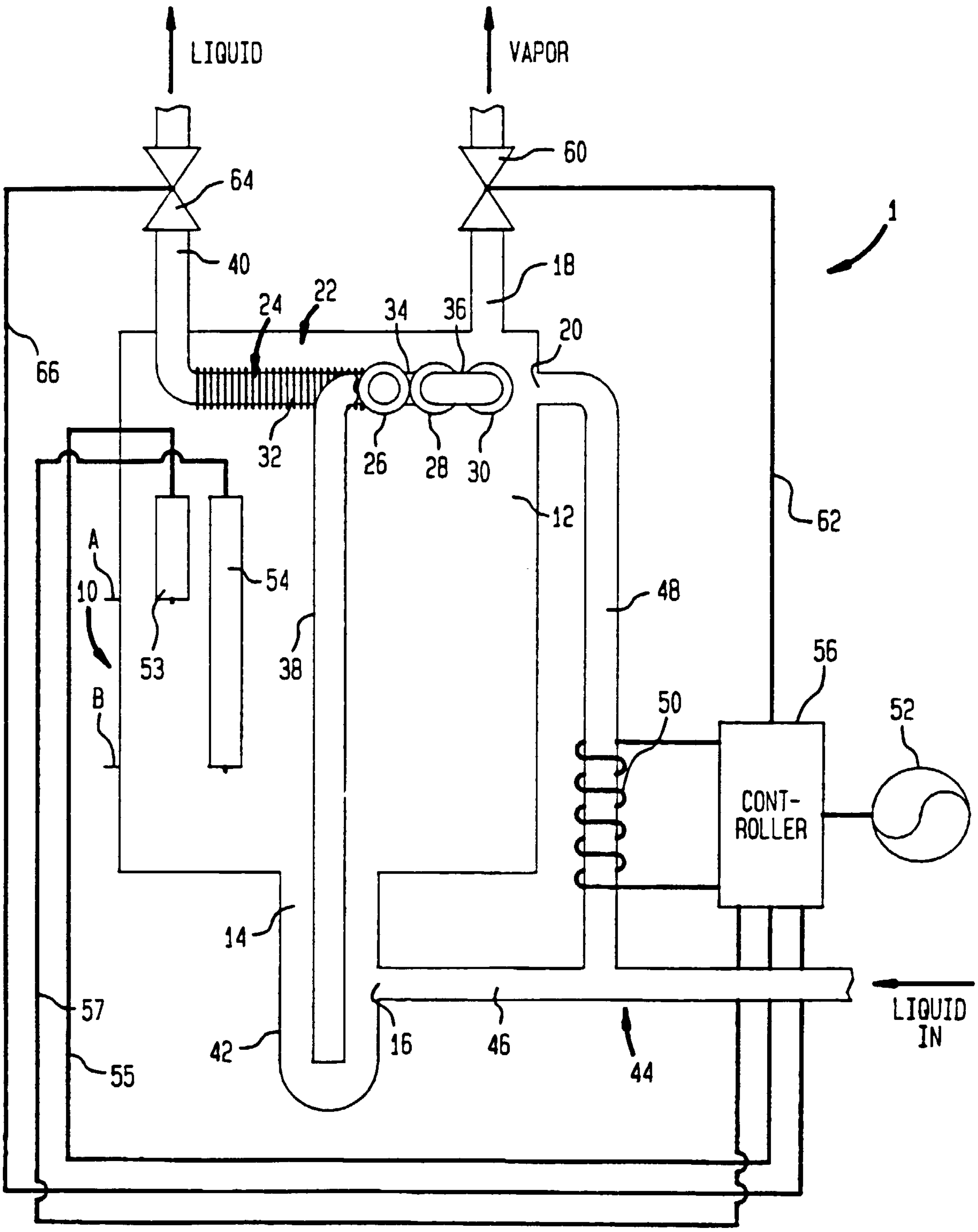
a remotely activated valve in said vapour outlet;

said level detector means also detects when said liquid phase falls below a lower set point level;

said heater activation means comprises a controller also having means responsive to said level detector means for opening said valve when said liquid phase falls below said lower set point level.

7. A cryogen delivery apparatus according to claim 4 or claim 5, wherein said actuable heater means is positioned below said upper set point level.

FIG.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